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Radiative decays of single heavy flavour baryons

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Abstract. The electromagnetic transitions between ($J^P = \frac{3}{2}^+$) and ($J^P = \frac{1}{2}^+$) baryons are important decay modes to observe new hadronic states experimentally. For the estimation of these transitions widths, we employ a non-relativistic quark potential model description with color Coulomb plus linear confinement potential. Such a description has been employed to compute the ground-state masses and magnetic moments of the single heavy flavor baryons. The magnetic moments of the baryons are obtained using the spin-flavor structure of the constituting quark composition of the baryon. Here, we also define an effective constituent mass of the quarks (ecqm) by taking into account the binding effects of the quarks within the baryon. The radiative transition widths are computed in terms of the magnetic moments of the baryon and the photon energy. Our results are compared with other theoretical models.

PACS. 12.39.Jh Nonrelativistic quark model – 12.39.Pn Potential models – 14.20.Lq Charmed baryons – 14.20.Mr Bottom baryons

1 Introduction

Recent experimental observations of excited charmed baryons by Belle and BABAR Collaborations [1,2] and new bottom baryons states like $\Sigma_b^{\pm}$, $\Sigma_b^{*\pm}$ and Ξ_b^- by CDF [3] and Ξ_b^- by DØ have generated an increasing interest on heavy baryon spectroscopy. It is striking that baryons containing one or two heavy charm or beauty flavour could play an important role in our understanding of QCD at the hadronic scale [4]. The copious production of heavy quarks at LEP, Fermilab Tevatron, CERN and B factories, opened up rich spectroscopic study of heavy hadrons. Many theoretical models [5–14] have also predicted the heavy baryon mass spectrum. The non-relativistic quark model (NRQM) [15] has been able to explain very nicely the mass spectrum of light baryons. Though the experimental and theoretical data on the properties of heavy flavour mesons are plenty available in the literature, the masses of all these heavy baryons have not been measured yet experimentally [16]. Thus, the recent predictions about the heavy baryon mass spectrum have become a subject of renewed interest due to the experimental facilities at Belle, BABAR, DELPHI, CLEO, CDF etc. [1,2,17–20]. These experimental groups have been successful in discovering heavy baryonic states along with other heavy flavour mesonic states and it is expected that more heavy flavour baryon states will be detected in the near future. Most of the new states are within the heavy flavour sector with one or more heavy flavour content and some of them are far from most of the theoretical predictions. Though there is consensus among the theoretical predictions on the ground-state masses [8,9], there is little agreement among the model predictions of the properties like spin-hyperfine splitting among the $J^P = \frac{1}{2}^+$ and $J^P = \frac{3}{2}^+$ baryons, the form factors [8], magnetic moments etc. [11]. All these reasons make the study of the heavy flavour spectroscopy extremely rich and interesting. The study of heavy baryons further provides an excellent laboratory to understand the dynamics of light quarks in the vicinity of heavy flavour quarks in bound states.

Apart from spectroscopy, various decay processes of the heavy flavour baryons are more important to observe new hadronic states experimentally. The strong decays are expected to dominate the branching rates of charmed baryons. In fact, most of the experimentally discovered channels of ground-state charmed baryons are the one- and two-pion transitions [21]. Although the electromagnetic strength is weaker than that of the strong interaction, radiative channels are not phase space suppressed as

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in the case of pion transitions. Therefore, some radiative decay modes are expected to contribute significantly to some heavy baryon branching fractions. The recent observations of CLEO confirm the importance of the radiative channels even though their contributions to some heavy baryon widths are relatively small compared to other decay modes. Many theoretical models have predicted the heavy baryon mass spectrum [5–14]. Nevertheless, the new experimental data of the charmed baryons can be used to test the success and validity of the different phenomenological models available in the literature.

Although radiative decays are well measured in the case of $D^* \to D\gamma$, $D_s^+ \to D_s^+\gamma$, only very few cases of $\Xi_c'^0 \to \Xi_c^0 + \gamma$, $\Xi_c'^+ \to \Xi_c^+ + \gamma$ and $\Omega_c^{*0} \to \Omega_c^0 + \gamma$, have been reported [22]. On the theoretical side, radiative decays of the heavy hadrons are calculated within the framework of the Heavy Hadron Chiral Perturbation Theory (HHCPT) and are available in [23–26]. It has been shown that electromagnetic interactions of heavy mesons contain only one coupling constant while heavy baryons transitions are determined in terms of two indepedent coupling constants. Moreover, based on the same theory, a small enhancement in the $\Sigma_Q^* \to \Lambda_Q\gamma$ radiative decay amplitudes was predicted [27] due to an electric quadrapole $E2$ interaction. On the other hand, electromagnetic transitions of excited Λ_Q baryons were analyzed in the Heavy Hadron Chiral Perturbation Theory (HHCPT) [28] and in the bound-state picture [29]. They show that the charmed baryons decay channels are severely supressed, however, the bottom baryons may have significant branching ratios. Some interesting predictions for charmed baryons within the frame of a relativistic quark model (RQM) are presented in ref. [30] Finally, the light-cone QCD sum rules in the leading order of the Heavy Quark Effective Theory (HQET) were also used [31] to analyze radiative decays of heavy baryons. In the heavy flavour sector, the non-relativistic dynamics of heavy quarks is a reasonable assumption as their masses are heavier than those in the light flavour sector.

In this paper, we compute the masses and magnetic moments of the single heavy flavor baryons using the Coloumb plus linear as the confinement inter-quark potential in a non-relativistic framework. The magnetic moments of the baryons are obtained using the spin-flavor structure of the constituent quark mass (cqm) parameters employed in the model as well as with an effective constituent mass of the quarks (ecqm) by taking into account the binding effects of the quarks constituting the baryon. We use the present values of magnetic moments of single heavy flavor baryons to obtain the radiative transition widths.

The paper is organized as follows. In sect. 2 of this paper, the basic methodology adopted for the present study of computing the masses of the single heavy flavour baryons is described. The electromagnetic radiative decay width containing single heavy flavour baryons is described in sect. 3. In sect. 4, we present our results and discuss the important features and conclusions of the present study.

Table 1. The present model parameters with the variational parameter λ. $m_u = m_d = 338$, $m_s = 420$, $m_c = 1380$, $m_b = 4275$ (in MeV).

System	λ in units of Bohr radius	β in units of (Bohr energy)$^{\nu+1}$
Charm baryons	3.07	1.262
Beauty baryons	5.57	10.000

2 Methodology

We start with the color singlet Hamiltonian of the baryonic system as

$$H = -\sum_{i=1}^{3} \frac{\nabla_i^2}{2m_i} + \sum_{i<j} V_{ij}, \tag{1}$$

where the interquark potential

$$V_{ij} = -\frac{2\alpha_s}{3}\frac{1}{x_{ij}} + \beta\, x_{ij}^{\nu} + V_{spin}(ij),$$

where,

$$x_{ij} = |\vec{x}_i - \vec{x}_j| = |\vec{r}_{ij}|. \tag{2}$$

Here, α_s is the running strong coupling constant, β is the interquark confinement strength of the potential and V_{spin} is the spin-dependent part of the two-body system. For the present study, we considered $\alpha_s(\mu_0 = 1\,\mathrm{GeV}) \approx 0.7$. One of the most tricky and important components of hadron spectroscopy is to predict correctly the spin-hyperfine splitting among the $J^P = \frac{3}{2}^+$ and $J^P = \frac{1}{2}^+$ baryons. There exist many attempts starting from the standard OGE potential, which corresponds to a free gluon exchange, to confined gluon exchange [32–34]. The free gluon exchange interaction between the point-like quarks leads to the delta function behavior, while the effect of confinement of the gluons as well as the finite size of the quarks warrant smoothening of the delta function. One of the most suitable form is provided by [4,11,35]

$$V_{spin} = \sum_{i<j} V_{spin}(ij) = -\frac{A}{4}\alpha_s \sum_{i<j} \vec{\lambda}_i \cdot \vec{\lambda}_j \frac{e^{\frac{-r_{ij}}{r_0}}}{r_{ij} r_0^2} \frac{\vec{\sigma}_i \cdot \vec{\sigma}_j}{6 m_i m_j}. \tag{3}$$

Here, the parameter A and the regularization parameter r_0 are considered as the hyperfine parameters of the model. It is closely similar to the form given by [4,11] except the way we treat the parameter r_0. Here we treat r_0 as a hyperfine parameter related to gluon dynamics, and hence independent of the masses of the interacting quarks as treated by [4]. All other parameters of the model including the quark masses are obtained from the study of mass spectra of the single heavy flavor baryons [35]. The parameters of the model and the masses of the single heavy flavour baryons computed in this scheme are listed in tables 1 and 3, respectively.

Another scheme to study the three-body system is the Hypercentral Model (HCM), where the Hamiltonian for

Table 2. Quark model parameters in the hypercentral model (HCM).

Quark masses	$m_u = 338$ (MeV)
	$m_d = 350$ (MeV)
	$m_s = 500$ (MeV)
	$m_c = 1700$ (MeV)
	$m_b = 4510$ (MeV)
Model parameter	$b = 13.6$, $\frac{\beta}{m\,\tau} = 1$ (MeV)$^{p+1}$

Table 3. Masses and photon energy in MeV ($k = m_B - m_{B'}$) of the single heavy flavour baryons.

Decay	Present			HCM		
$B \to B'\gamma$	m_B	$m_{B'}$	k	m_B	$m_{B'}$	k
$\Sigma_c^+ \to \Lambda_c^+\gamma$	2445	2286	159	2461	2290	171
$\Sigma_c^{*++} \to \Sigma_c^{++}\gamma$	2507	2445	62	2516	2451	65
$\Sigma_c^{*+} \to \Sigma_c^+\gamma$	2507	2445	62	2526	2461	65
$\Sigma_c^{*0} \to \Sigma_c^0\gamma$	2507	2445	62	2536	2471	65
$\Sigma_c^{*+} \to \Lambda_c^+\gamma$	2507	2286	221	2526	2290	236
$\Omega_c^{*0} \to \Omega_c^0\gamma$	2758	2674	84	2757	2696	61
$\Xi_c^{*+} \to \Xi_c^+\gamma$	2637	2464	173	2672	2485	187
$\Xi_c^{*0} \to \Xi_c^0\gamma$	2637	2464	173	2680	2494	186
$\Sigma_b^0 \to \Lambda_b^0\gamma$	5807	5624	183	5811	5629	182
$\Sigma_b^{*+} \to \Sigma_b^+\gamma$	5827	5807	20	5823	5801	22
$\Sigma_b^{*0} \to \Sigma_b^0\gamma$	5827	5807	20	5834	5811	23
$\Sigma_b^{*-} \to \Sigma_b^-\gamma$	5827	5807	20	5844	5821	23
$\Sigma_b^{*0} \to \Lambda_b^0\gamma$	5827	5624	203	5834	5629	205
$\Omega_b^{*-} \to \Omega_b^-\gamma$	6186	6156	30	6065	6005	60
$\Xi_b^{*0} \to \Xi_b^0\gamma$	5939	5827	112	5936	5872	64
$\Xi_b^{*-} \to \Xi_b^-\gamma$	5939	5827	112	5943	5887	56

baryons can be written as

$$H = \frac{P_\rho^2}{2m_\rho} + \frac{P_\lambda^2}{2m_\lambda} + V(\rho,\lambda) = \frac{P_x^2}{2m} + V(x). \qquad (4)$$

The hypercentral potential $V(x)$ is given as

$$V(x) = -\frac{\tau}{x} + \beta x^p + \kappa + V_{spin}(x). \qquad (5)$$

Here, x is written in terms of the Jacobi coordinates (ρ, λ) as $\sqrt{\lambda^2+\rho^2}$ with $\vec{\rho} = \frac{1}{\sqrt{2}}(\vec{r}_1 - \vec{r}_2)$ and $\vec{\lambda} = \frac{1}{\sqrt{6}}(\vec{r}_1 + \vec{r}_2 - 2\vec{r}_3)$.

The parameters in the hypercentral model [11] and the masses of the single heavy flavour baryons computed in this scheme are listed in the tables 2 and 3, respectively.

3 Radiative decay of single heavy flavour baryons

The electromagnetic radiative decay width can be expressed in terms of the radiative transition magnetic moment (in μ_N) and photon energy (k) as [36]

$$\Gamma_\gamma = \frac{k^3}{4\pi}\frac{2}{2J+1}\frac{e^2}{m_p^2}\mu^2_{B\to B'\gamma}; \qquad (6)$$

here, m_p is the proton mass, k is the photon energy and it is expressed as $m_B - m_{B'}$. $\mu_{B\to B'\gamma}$ is the radiative transition magnetic moments (in nuclear magnetons), which are expressed in terms of the magnetic moments of the constituting quarks (μ_i) of the initial and final state of the baryon [36]. The radiative transition magnetic moment is calculated as

$$\mu_{B\to B'\gamma} = \langle B|\hat{\mu}_{B'z}|B'\rangle\,. \qquad (7)$$

In the case of $\Sigma_c^+ \to \Lambda_c^+\gamma$, we can write the transition magnetic moment as $\langle\Sigma_c^+|\hat{\mu}_{\Lambda_c^+z}|\Lambda_c^+\rangle$.

Using the spin wave function of $|\Lambda_c^+\rangle$ and $|\Sigma_c^+\rangle$ given by [37]

$$|\Lambda_c^+\rangle = -|udc\rangle\chi^{\frac{1}{2}}_{MA} = -|udc\rangle\frac{1}{\sqrt{2}}|(\uparrow\downarrow - \downarrow\uparrow)\uparrow\rangle, \qquad (8)$$

$$|\Sigma_c^+\rangle = |udc\rangle\chi^{\frac{1}{2}}_{MS} = |udc\rangle\left(\frac{-1}{\sqrt{6}}\right)|[(\uparrow\downarrow - \downarrow\uparrow)\uparrow -2\uparrow\uparrow\downarrow]\rangle. \qquad (9)$$

We can write

$$\hat{\mu}_{\Lambda_c^+z} = \mu_u\sigma_z(1) + \mu_d\sigma_z(2) + \mu_c\sigma_z(3), \qquad (10)$$

$$\hat{\mu}_{\Lambda_c^+z}\chi^{\frac{1}{2}}_{MA} = \frac{1}{\sqrt{2}}[\mu_u|(\uparrow\downarrow + \downarrow\uparrow)\uparrow\rangle + \mu_d|(-\uparrow\downarrow - \downarrow\uparrow)\uparrow\rangle + \mu_c|(\uparrow\downarrow - \downarrow\uparrow)\uparrow\rangle]. \qquad (11)$$

Thus, we get the transition magnetic moment as

$$\mu_{\Sigma_c^+-\Lambda_c^+} = \left\langle\Sigma_c^+|\hat{\mu}_{\Lambda_c^+z}|\Lambda_c^+\right\rangle \qquad (12)$$

and it is further expressed in terms of the constituting quark magnetic moment of the baryon using eqs. (8) to (11) as

$$\mu_{\Sigma_c^+-\Lambda_c^+} = -\frac{1}{\sqrt{12}}[2\mu_u - 2\mu_d] = -\frac{1}{\sqrt{3}}[\mu_u - \mu_d]. \qquad (13)$$

Similarly, we compute the radiative transition magnetic moment ($\mu_{B\to B'\gamma}$) of different baryonic transitions of the single charm and beauty baryons. The results are listed in the table 4. Here, the magnetic moment (μ_i) of the constituting quarks are computed as [11,35]

$$\mu_i = \left\langle \phi_{sf}\left|\frac{e_i}{2m_i^{eff}}\sigma_i\right|\phi_{sf}\right\rangle, \qquad (14)$$

where, e_i and σ_i represents the charge and the spin of the quarks forming the baryonic state. We have employed the spin-flavour wave function ($|\phi_{sf}\rangle$) of the symmetric and

Table 4. Transition magnetic moment ($\mu_{B\to B'\gamma}$) of single heavy flavour baryons in terms of keV (* indicates the $J^P = \frac{3}{2}^+$ state.)

Decay	$\mu_{B\to B'\gamma}$ (in μ_N)	Present		HCM	
		(ecqm)	(cqm)	(ecqm)	(cqm)
$\Sigma_c^+ \to \Lambda_c^+\gamma$	$-\frac{1}{\sqrt{3}}(\mu_u - \mu_d)$	−1.347	−1.602	−1.537	−1.584
$\Sigma_c^{*++} \to \Sigma_c^{++}\gamma$	$\frac{2\sqrt{2}}{3}(\mu_u - \mu_c)$	1.080	1.317	1.320	1.398
$\Sigma_c^{*+} \to \Sigma_c^+\gamma$	$\frac{\sqrt{2}}{3}(\mu_u + \mu_d - 2\mu_c)$	0.008	0.009	0.100	0.105
$\Sigma_c^{*0} \to \Sigma_c^0\gamma$	$\frac{2\sqrt{2}}{3}(\mu_d - \mu_c)$	−1.064	−1.299	−1.124	−1.187
$\Sigma_c^{*+} \to \Lambda_c^+\gamma$	$\frac{\sqrt{2}}{\sqrt{3}}(\mu_u - \mu_d)$	1.857	2.265	2.117	2.239
$\Omega_c^{*0} \to \Omega_c^0\gamma$	$\frac{2\sqrt{2}}{3}(\mu_s - \mu_c)$	−0.908	−1.128	−0.916	−0.935
$\Xi_c^{*+} \to \Xi_c^+\gamma$	$\frac{\sqrt{2}}{\sqrt{3}}(\mu_u - \mu_s)$	0.9912	1.222	1.108	1.166
$\Xi_c^{*0} \to \Xi_c^0\gamma$	$\frac{\sqrt{2}}{\sqrt{3}}(\mu_d - \mu_s)$	−0.120	−0.148	−0.208	−0.218
$\Sigma_b^0 \to \Lambda_b^0\gamma$	$-\frac{1}{\sqrt{3}}(\mu_u - \mu_d)$	−1.365	−1.602	−1.415	−1.583
$\Sigma_b^{*+} \to \Sigma_b^+\gamma$	$\frac{2\sqrt{2}}{3}(\mu_u - \mu_b)$	2.223	2.616	2.303	2.586
$\Sigma_b^{*0} \to \Sigma_b^0\gamma$	$\frac{\sqrt{2}}{3}(\mu_u + \mu_d - 2\mu_b)$	0.429	0.504	0.459	0.516
$\Sigma_b^{*-} \to \Sigma_b^-\gamma$	$\frac{2\sqrt{2}}{3}(\mu_d - \mu_b)$	−0.683	−0.803	−0.692	−0.776
$\Sigma_b^{*0} \to \Lambda_b^0\gamma$	$\frac{\sqrt{2}}{\sqrt{3}}(\mu_u - \mu_d)$	1.925	2.265	1.995	2.239
$\Omega_b^{*-} \to \Omega_b^-\gamma$	$\frac{\sqrt{2}}{3}(\mu_s - \mu_b)$	−0.523	−0.632	−0.476	−0.523
$\Xi_b^{*0} \to \Xi_b^0\gamma$	$\frac{\sqrt{2}}{\sqrt{3}}(\mu_u - \mu_s)$	1.036	1.222	1.051	1.166
$\Xi_b^{*-} \to \Xi_b^-\gamma$	$\frac{\sqrt{2}}{\sqrt{3}}(\mu_d - \mu_s)$	−0.124	−0.147	−0.196	−0.218

antisymmetric states of the baryons as used in [11,35]. Here, m_i^{eff} corresponds to the mass of the bound quark inside the baryons taking into account its binding interactions with other two quarks described by the Hamiltonian given in eq. (1) in the case of the present model and in eq. (4) in the case of the hypercentral model (HCM). The effective mass for each of the constituting quark m_i^{eff} can be defined as [11,35]

$$m_i^{eff} = m_i \left(1 + \frac{\langle H \rangle}{\sum_i m_i}\right), \tag{15}$$

where $\langle H \rangle = E + \langle V_{spin} \rangle$ such that the corresponding mass of the baryon with the spin angular momentum J is given by

$$M^J = \sum_i m_i + \langle H \rangle_J = \sum_i m_i^{eff}. \tag{16}$$

Here, m_i's are the respective model quark mass parameters. Accordingly, the effective masses of the u and d quarks are obtained from the baryonic states of udc and udb, respectively.

Using the masses of the participating baryons in the decay $(m_B, m_{B'})$ and the transition magnetic moments of the single heavy flavour baryons with and without the effective mass of the constituent quarks, we compute the radiative transition widths (keV). The transition magnetic moments with and without the effective mass of the constituent quarks are refered as ecqm and cqm, respectively and listed in table 4. Accordingly, the transition widths are computed with ecqm and cqm, respectively, and are listed in table 5.

4 Conclusion and discussion

We have employed a simple non-relativistic variational approach with Coulomb plus linear potential to compute the radiative decay of the single heavy flavour baryons in terms of radiative transition magnetic moments and photon energy. The model parameters are obtained to get the ground-state masses of the Qqq systems [35]. Masses and photon energy of the single heavy flavour baryons in the present model as well as with the HCM are listed in table 3. The computed radiative transition widths are listed in table 5 and compared with other theoretical models. The present result for the $\Sigma_c^+ \to \Lambda_c^+\gamma$ transition width (60.55 keV) obtained with the consideration of the effective quark mass (ecqm) is in good agreement with

Table 5. Radiative transition decay widths ($\Gamma_{B\to B'\gamma}$) of singly heavy flavour baryons in terms of keV (* indicates the $J^P = \frac{3}{2}^+$ state.)

Decay	Present		HCM		Others[a]
	(ecqm)	(cqm)	(ecqm)	(cqm)	
$\Sigma_c^+ \to \Lambda_c^+\gamma$	60.55	85.59	97.98	104.03	98.70 [36]
					60.70 [38]
					87.00 [39]
					89.00 [40]
$\Sigma_c^{*++} \to \Sigma_c^{++}\gamma$	1.15	1.71	1.98	2.22	1.70 [36]
					3.04 [39]
$\Sigma_c^{*+} \to \Sigma_c^+\gamma$	$< 10^{-4}$	$< 10^{-4}$	0.01	0.01	0.01 [36]
					0.14 [38]
					0.19 [39]
$\Sigma_c^{*0} \to \Sigma_c^0\gamma$	1.12	1.66	1.44	1.60	1.20 [36]
$\Sigma_c^{*+} \to \Lambda_c^+\gamma$	154.48	229.85	244.39	273.48	250.00 [36]
					151.00 [38]
					230.00 [40]
					130.00 [41]
$\Omega_c^{*0} \to \Omega_c^0\gamma$	2.02	3.13	0.82	0.79	0.36 [36]
$\Xi_c^{*+} \to \Xi_c^+\gamma$	63.32	96.34	99.94	110.77	124.00 [36]
					75.60 [40]
					52.00 [41]
$\Xi_c^{*0} \to \Xi_c^0\gamma$	0.30	0.46	1.15	1.27	0.80 [36]
					0.90 [40]
					0.66 [41]
$\Sigma_b^0 \to \Lambda_b^0\gamma$	94.79	130.50	100.39	125.43	–
$\Sigma_b^{*+} \to \Sigma_b^+\gamma$	0.08	0.11	0.11	0.14	0.46 [41]
					1.26 [31]
$\Sigma_b^{*0} \to \Sigma_b^0\gamma$	$< 10^{-3}$	$< 10^{-3}$	0.01	0.01	0.03 [41]
					0.08 [31]
					0.15 [39]
$\Sigma_b^{*-} \to \Sigma_b^-\gamma$	0.01	0.02	0.02	0.03	0.11 [41]
$\Sigma_b^{*0} \to \Lambda_b^0\gamma$	128.62	178.14	142.13	179.25	114.00 [41]
					344.00 [31]
					251.00 [39]
$\Omega_b^{*-} \to \Omega_b^-\gamma$	0.03	0.04	0.20	0.24	–
$\Xi_b^{*0} \to \Xi_b^0\gamma$	18.79	26.14	3.60	4.44	–
$\Xi_b^{*-} \to \Xi_b^-\gamma$	0.09	0.13	0.03	0.03	1.50 [41]

([a]) Ref. [39]: HQS; refs. [41,31]: QCD sum rules; refs. [36,40]: NRQM; ref. [38]: RQM.

the predictions of [38] based on the Relativistic Three-Quark Model (RQM) containing a Lagrangian describing the coupling of heavy baryons of the constituting quarks, while without considering the binding energy effect (cqm), the computed width (85.59 keV) is in agreement with the value of 87.00 keV of [39], the model based on the heavy quark symmetry with the quark-diquark description of the single heavy flavour baryon (HQS) and 89.00 keV of [40], the non-relativistic model based group theoretical mass formula containing a $SU(3)$ breaking term in the Hamiltonian (NRQM). However the hypercentral model prediction of 97.98 keV with the effective mass consideration is in agreement with the predicted value of 98.7 keV by [36], the non-relativistic model with the harmonic confinement potential in the Isgur-Karl scheme. In the transition width of $\Sigma_c^{*++} \to \Sigma_c^{++}\gamma$, our present prediction of 1.71 keV with (cqm) is in good agreement with that of [36].

In the case of $\Sigma_c^{*+} \to \Sigma_c^+\gamma$, the two orders of magnitude discrepancy obtained in the present calculation is due to the order of magnitude difference seen in the transition magnetic moment as listed in table 4. However, the HCM predictions in this case are in agreement with that of [36]. In the case of $\Sigma_c^{*+} \to \Lambda_c^+\gamma$, our predicted width with ecqm (154.48 keV) is in good agreement with that of [38] and that with cqm (229.85 keV) is in excellent agreement with the predictions by [40]. The hypercentral model (HCM) predictions with ecqm and cqm are also comparable with the predictions of [36] and [40]. We find larger variations among the predictions of transition widths in the case of beauty baryons as seen from table 5. The future experimental results on these transition widths can only resolve these variations among different model predictions.

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